

# PATENT SPECIFICATION

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- (72) Inventors BRIAN GEOFFREY BLATCHFORD, JOHN ·  
JEFFREY SHORTER and VICTOR JAMES ·  
WOOLNOUGH ·



## (54) IMPROVEMENTS IN OR RELATING TO ARTIFICIAL LIMBS

(71) We, CHAS. A. BLATCHFORD & SONS LIMITED, a British company, of Lister Road, Basingstoke, Hampshire, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to artificial limbs and its purpose is to provide an artificial limb which is, for a given load-bearing capability, lighter in weight than limbs commonly in use at present. The invention is intended particularly to apply to the shin of an artificial leg, although it is not limited to that application.

According to this invention an artificial limb includes a load-bearing structure which comprises a closed tubular framework made up of elongate members which together wholly or partly enclose a space, which are disposed so as to support a load applied to the structure, and which are of fibre reinforced plastics material. Such a framework could be of net-like form. The structure may have inserts moulded into it, to provide attachment points, and/or to provide an interface or interfaces. Thus by providing an interface at, for example, the lower extremity of the shin of an artificial leg, a foot can be connected to the shin. The shin may be part of an above-knee or a below-knee leg, or a leg having some other level of amputation, as required. As another example, an interface could be arranged at the lower end of the thigh of an artificial leg, for attachment of a knee joint unit or a knee housing. In this way the load-bearing structure in accordance with the invention may be used in a modular system of artificial limb construction.

Examples of fibres are:—carbon fibres, glass fibres, and polyester fibres. Mixtures of fibres could be used. One fibre-reinforced plastics material which has been found suitable is a “tow” which is a loose bundle of numerous fine carbon fibres impregnated with a hardenable epoxy resin. Such a bundle of carbon fibres, when the resin has become hard, is of

great strength in relation to its weight, yet before the resin has hardened the “tow” can be quite readily shaped, for instance by winding round a former or a series of formers.

The invention also includes an artificial leg having a load-bearing shin which shin comprises a closed tubular framework made up of a) elongate members extending axially of the shin and b) elongate members extending diagonally to, and around, the axially extending members, the elongate members i) together enclosing a space; ii) being of plastics material reinforced with carbon fibres; and iii) being bonded together at points where they cross or meet.

The invention also includes a method of making a load-bearing structure for an artificial limb, comprising:—impregnating a bundle of fibres with a non-hardened or partly hardened plastics material; winding the bundle repeatedly around an arrangement of formers so as to build up a closed tubular framework of elongate members which together wholly or partly enclose a space and are so disposed as to support an applied load; hardening, or completing hardening of, the elongate members; and removing all or some of the formers.

One embodiment of the invention will now be described by way of example, with reference to the accompanying diagrammatic drawings, in which:—

Figure 1 is a front elevation of an artificial shin structure;

Figure 2 is a side elevation of the structure of Figure 1, as viewed from the right hand side of that Figure;

Figure 3 is a rear elevation of the structure, as viewed from the right hand side of Figure 2;

Figure 4 is a section on the plane A—A of Figure 2; and

Figure 5 is a diagram showing how plastics-impregnated fibrous tows are wound to produce the structure of Figures 1 to 4.

It will be appreciated, particularly by referring to Figure 4, that the structure of Figures 1 to 4 is, very generally, cylindrical. Figure

5 is an opened-out projection of such cylindrical structure.

Figures 1 to 4 show an artificial limb load-bearing structure to form the basis of a shin and which extends from a knee joint to an ankle joint. It comprises an upper part generally indicated at B and a lower part generally indicated at C. The upper part B has various moulded-in connections of metal, as will be discussed below, such that the structure can be connected to a knee mechanism and thigh of currently conventional type. Also the space frame shape of the upper part B is such as to enclose a space in which can be disposed a conventional pneumatic swing phase or other control device. This upper part B would replace the metal load-bearing "cradle" at present used. The lower part C would replace the metal load-bearing tube at present used. These upper and lower parts form a continuous, unitary load-bearing space frame structure of elongate members, as shown. These include generally vertical members 1C, horizontal hoops 2C, and helical or diagonal members 3C. These members are made of carbon fibres impregnated with epoxy resin, in other words, of epoxy resin reinforced with carbon fibres.

As mentioned, various metal connections are moulded in. These include an axially aligned pair of spaced, externally grooved metal rings 1, 2; in the completed artificial leg their axis would be the knee axis and the knee bolt ends, or equivalent members, would be connected to these rings. An externally grooved, generally oval-shaped metal connection 8 is moulded in at the rear of the upper part B, to form the lower anchorage for a back-check cord (not shown). Another axially aligned pair of spaced, externally grooved rings

9, 10 provide mountings at each side for the lower end of a pneumatic swing phase control unit (not shown) of well-known type. At the lower or ankle end of the shin another pair of spaced, externally grooved rings 20, 21 provide mountings at each side for the ends of an ankle bearing pin (not shown) on which would be rotatably mounted a seating, for example for connecting an inverted U-bolt by which the foot is connected to the shin. The grooved part of each ring 1, 2, 9, 10, 20, 21 is square, see Figure 5, for rings 20, 21, to prevent rotation of the ring, the carbon fibre tow being wound on the grooved square part. In an alternative arrangement an interfacing member could be moulded into the lower end of the space frame structure, to mate with another interface on the foot.

All the rings 1, 2, 9, 10, 20, 21 and the connection S also constitute formers around which, in making the space frame, the soft tow of fibres impregnated with plastics material can be wound. Additional formers, in the form of smaller externally grooved rings, are disposed as indicated by 11, 12, 13, 14, and 15, 16, 17, 18. Further formers are arranged at the lower end of the structure: at the front a generally semicircular former 22 constitutes also a pad to abut an instep rubber buffer of the foot and at the back a generally circular drum-like former 19 constitutes also a pad to abut a heel rubber buffer of the foot.

The reference numerals 4, 5, 6, 7 indicate locations where formers are used during winding of the tow, but which are removed when the tow has hardened.

A material which has been found suitable is as follows:—

#### Carbon Fibre:

Courtaulds "Crafil" Type A (III) E/A—S.  
Resin:

Ciba-Geigy "Araldite" (Registered Trade Mark) Resin CY219—100 parts by weight.  
" Hardener HY219—50 parts by weight.  
" Accelerator DY219—2 parts by weight.

The carbon fibres are impregnated with the wet resin to a ratio of 50:50 by weight. The impregnation can be carried out by passing an unimpregnated bundle of carbon fibres through an impregnating bath or jig of known type, the bath containing the liquid resin formulation.

The wet resin-impregnated tow is wound on a winding jig which comprises a pedestal on which are removably mounted in the correctly spaced positions the various formers referred to above. The pedestal also includes formers which are fixed to it and which are removed with it from the space frame when the resin has become hard.

Given the numbers and arrangement of formers described above with reference to Figures 1 to 4, there are numerous possible winding sequences and experiments have been made, using a computer, to determine the best winding sequence or sequences. It will suffice here to describe one such sequence, with reference to Figure 5. This is an opened out, diagrammatic projection. Considering Figure 1 (the front elevation) and bearing in mind that it is a generally cylindrical structure, assume that the structure is cut centrally vertically down its front, and then opened out flat: the result will be the projection of Figure 5.

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In Figure 5 the various formers are shown with the reference numerals used above in connection with Figures 1 to 4. Some lines, it will be seen, end in numbered arrows; these indicate the former to which the winding in question leads. The winding is carried out in four main sequences, although fewer or more sequences could be used; in prototype manufacture four have been used: i) the vertical load-bearing members extending from the formers 1 and 2 at the top down to the formers 19 to 22 at the bottom; ii) the remaining members forming the cradle or upper part B; iii) the helically wound members; iv) the hoop-like members.

The presently preferred sequences are set out below. Each sequence may be repeated. For example, for the vertical members (i) and the cradle members (ii) the sequences would be repeated six times, to build up members of the required strength. Thus for example referring to a member 1C of Figures 1 to 3, it would be built up of 6 lengths of impregnated tow which lengths would become bonded together into the single elongate vertical load-bearing member 1C. For the helical and hoop-like members, the winding sequence for each would be repeated four times.

In the sequence given below, the numbers refer to the formers or former locations which are shown in the drawings, and the suffix C means that the winding is clockwise around a former, and the suffix A, anti-clockwise. One former, former 3, is shown in Figure 5 but not in Figures 1 to 4. This former 3 is an arcuately curved surface over which is wound the frame member seen between points 5 and 6 in Figures 1 and 3, and part of which member is seen in side elevation in Figure 2. In Figure 5, clockwise (C) or anti-clockwise (A), in relation to the formers 19 and 22, is as viewed from above.

The sequences are as follows:—

1. 16A — 11A — 1A — 10A — 15C —  
45 14C — 1C — 10C — 16A — 21C — 16C —  
21C — 15C — 21C — 15A — 18A —  
13A — 2A — 9A — 17C — 20A — 17A —  
20A — 18A — 20A — 19A — 21A —  
22A — 20A — 18C — 9A — 2A — 12A —  
50 17A. This winding, after being passed anti-clockwise around former 17A, is then continued as a first helical winding of approximately three inch pitch, leading up to 12A and thence to 11A whence it is continued as a second helical winding down to 16A. The sequence continues 19C — 17A — 18C, then a third helical winding up to 13C — 14C, then a fourth helical winding down to 15C — 22A — 18C. All these helical windings are of the same pitch and produce the criss-cross arrangement shown. This winding is repeated six times, although other numbers of windings could be used. After the sixth time, the tow is cut and the second winding is wound, as follows:—

2. 16C — 22A — 16A — 15A — 19C — 18A — 17A — 22A — 17C — 16C — 15A — 19A — 18A — 15A. This is repeated four times and then cut. The third winding is as follows:

3. 11C — 7C — 2A — 7A — 8A — 1C — 4C — 11C — 10C — 8A — 5C — 6C — 12A — 9A — 8C — 13A — 12A — 4A — 1C — 8C — 2C — 8A — 14C — 8A — 13C — 14C — 12C. This is repeated four times, then cut.

The fourth winding sequence is in fact several windings and consists of winding five separate hoops 2C around the structure of vertical and helical members already wound; for each hoop 2C a tow is wound round four times.

It will be understood that the above sequences provide only one method of building up the structure. Many other winding sequences are possible. For example, in the first sequence, that part of it which produces the vertical members, which are the main load-bearing members, could be repeated six times, while that part of it which produces members at the lower extremity could be repeated four times. Thus by having several separate sequences, members may be built up to a thickness according to the strength requirements. In general the vertical members provide for load-bearing whilst the helical and hoop-like windings take up torsion in the shin and prevent crushing.

It is desirable, before winding is started, to spray the insert formers with epoxy, to increase adhesion and to reduce the danger of electrolytic corrosion.

#### WHAT WE CLAIM IS:—

1. An artificial limb including a load-bearing structure which comprises a closed tubular framework made up of elongate members which together wholly or partly enclose a space, which are disposed so as to support a load applied to the structure, and which are of fibre reinforced plastics material.

2. An artificial limb according to claim 1 wherein the fibre is carbon fibre or glass fibre or polyester fibre.

3. An artificial limb according to claim 1 wherein the fibre is carbon fibre and the plastics material is an epoxy resin.

4. An artificial limb according to any preceding claim wherein the framework is of net-like form.

5. An artificial limb according to any preceding claim having inserts held in place by the fibre-reinforcing plastics material.

6. An artificial limb according to claim 5 wherein at least some of the inserts constitute supporting means for other parts of the artificial limb.

7. An artificial limb according to claim 6 wherein the load-bearing structure forms part of the shin of a leg and includes some inserts

7C

75

8C

85

9C

95

10C

105

110

115

120

125

which constitute supporting means for a knee joint unit or a knee housing.

8. An artificial limb according to claim 7 wherein some inserts constitute mounting means for an artificial foot.

9. An artificial limb according to claim 1 including elongate members which extend axially of the limb and members which extend transversely to the axis of the limb.

10. An artificial limb according to claim 9 including elongate members which are hoop-like and lie in planes substantially at right angles to axis of the limb.

11. An artificial leg having a load-bearing shin which shin comprises a closed tubular framework made up of a) elongate members extending axially of the shin and b) elongate members extending diagonally to, and around, the axially extending members, the elongate members i) together enclosing a space; ii) being of plastics material reinforced with carbon fibres; and iii) being bonded together at points where they cross or meet.

12. An artificial leg according to claim 11 wherein the plastics material is an epoxy resin.

13. An artificial leg according to claim 11 or claim 12 wherein the framework includes hoop-like members lying in planes substantially at right angles to the axially extending elongate members.

14. A method of making a load-bearing structure for an artificial limb, comprising:—  
impregnating a bundle of fibres with a non-hardened or partly hardened plastics material;  
winding the bundle repeatedly around an arrangement of formers so as to build up a closed tubular framework of elongate members which together wholly or partly enclose a space and are so disposed as to support an applied load; hardening, or completing hardening of, the elongate members; and removing all or some of the formers.

15. A method according to claim 14 wherein the fibres are of carbon or glass or polyester.

16. A method according to claim 14 wherein the plastics material is an epoxy resin.

17. A method according to any of claims 14 to 16 wherein some of the formers are constructed to constitute bearings or connections for other parts of the artificial limb.

18. An artificial limb including a load-bearing structure constructed and arranged substantially as herein described and shown in the accompanying drawings.

WITHERS & ROGERS,  
Chartered Patent Agents,  
148-150 Holborn, London, EC1N 2NT.  
Agents for the Applicants.

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COMPLETE SPECIFICATION

3 SHEETS

This drawing is a reproduction of  
the Original on a reduced scale  
Sheet 1

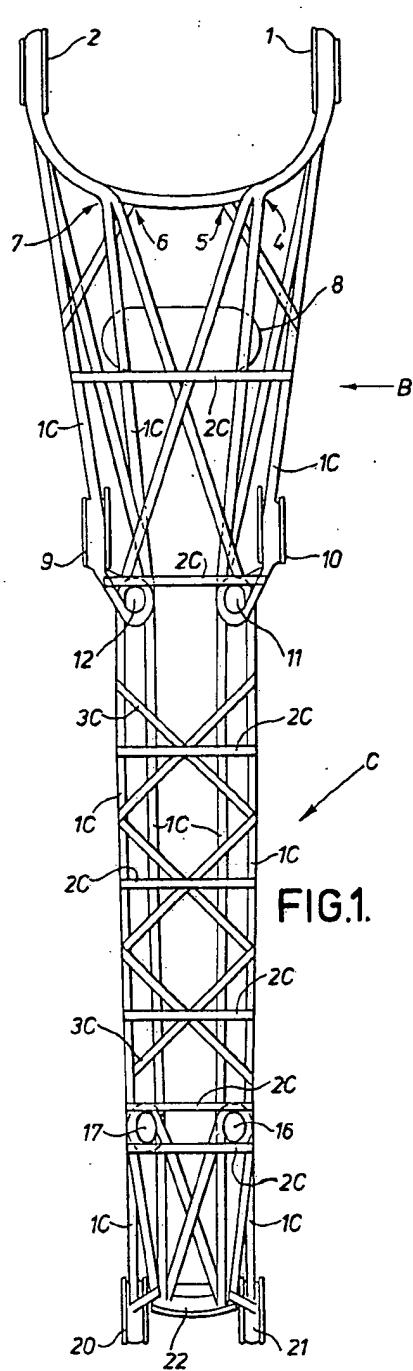


FIG.1.

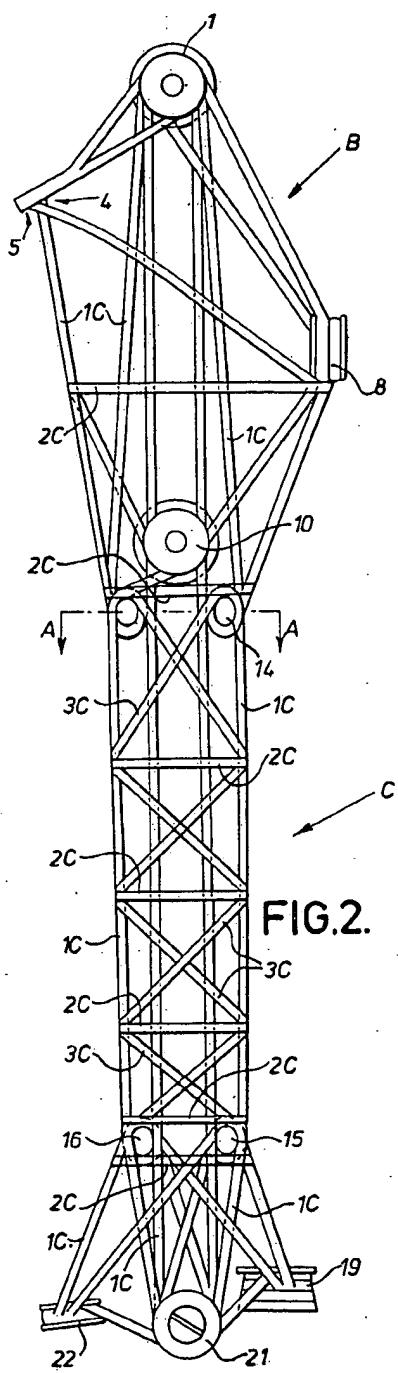
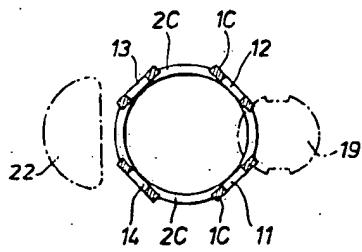
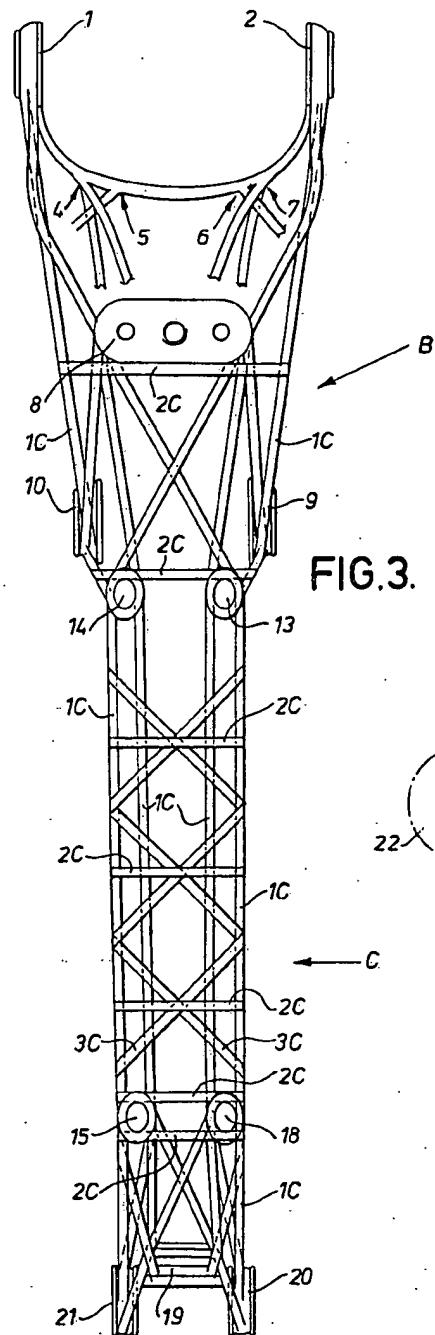


FIG.2.



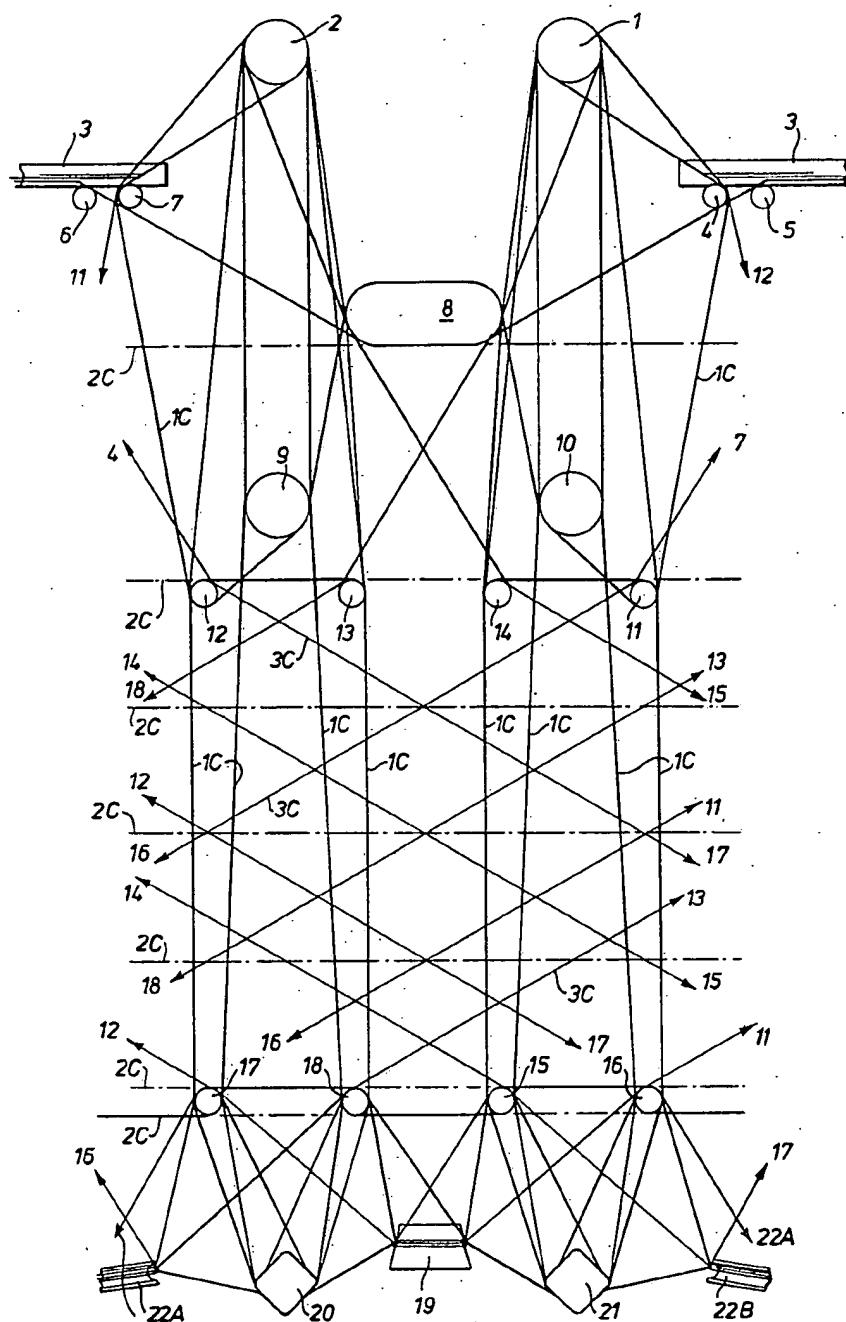


FIG.5.